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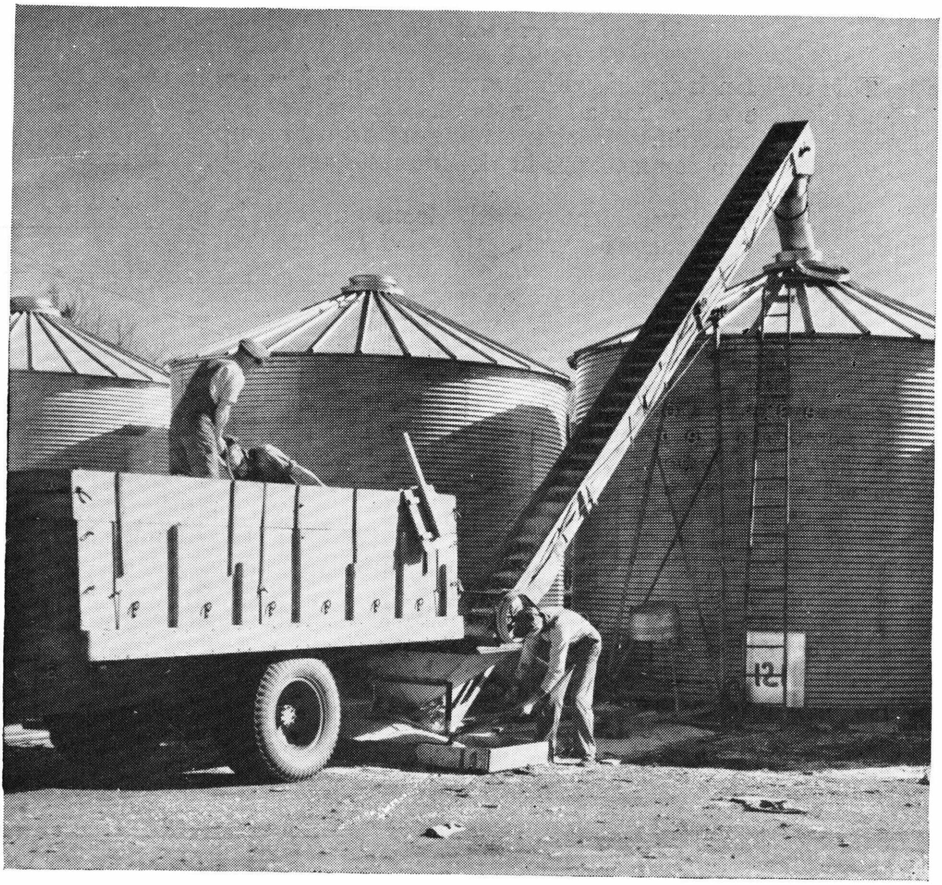
STORAGE OF SMALL GRAINS AND SHELLED CORN ON THE FARM



FARMERS' BULLETIN
No. 2009

U. S. DEPARTMENT OF AGRICULTURE

BALANCED ABUNDANCE

Protects producers and consumers
Stabilizes prices
Assures fair income
Helps conserve soil

This bulletin is issued with a view to aiding farmers in achieving the objective of balanced abundance. By balanced abundance we mean the production and maintenance of adequate supplies of grains and other farm commodities in the interests of both producers and consumers.

The Federal Government provides loans on grain in farm storage against the time that the grain is needed for domestic and foreign consumption. It enables farmers to obtain the full value of their grain as it is needed in the processes of orderly marketing. But providing the physical means of protecting the harvested grain on the farms as to both quantity and quality is the responsibility of the farmers themselves.

Surveys have shown that today there is insufficient farm storage to accommodate the great grain crops now being produced. Modern harvesting is done so rapidly, so much grain moves to market at once, that a farm without a granary to safeguard the quality of grain and to ease the flow to market is physically and economically handicapped. Some storage facilities have been built since the end of World War II, but clearly not enough to protect the Nation's grain supply which properly should be stored on the farms. More need to be built.

We hope that for the purposes here expressed our farmers will find useful the information and suggestions that are contained in this publication on farm storage.

Charles F. Brannan

Secretary of Agriculture.

Washington, D. C.

Issued September 1949

STORAGE OF SMALL GRAINS AND SHELLED CORN ON THE FARM[1]

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DEFINITE provisions for building adequate reserve supplies of grains are included in the Agricultural Adjustment Act of 1938 and the Agricultural Act of 1948. One of these is the provision for acreage allotments. Through the use of allotments and with the assistance of conservation payments, cooperating farmers can adjust their production in a way that assures abundant supplies, avoiding at the same time the wasteful use of their land. Acreage allotments for eligible grains, as for other crops, leave more acres for soil-conserving uses, thus making possible the building up of soil fertility. When supplies of eligible grain become excessive, marketing quotas may be voted into effect by producers as a means of making acreage allotments more effective, stabilizing production, and preventing soil depletion. When in effect, quotas assure supplies large enough to take care of normal needs plus an abundant reserve as a protection against future shortage.

[1] This bulletin was prepared by C. K. Shedd, senior agricultural engineer, Bureau of Plant Industry, Soils, and Agricultural Engineering, and R. T. Cotton, senior entomologist, Bureau of Entomology and Plant Quarantine, Agricultural Research Administration, in consultation with other representatives of their bureaus and the Grain Branch, Production and Marketing Administration, of the U. S. Department of Agriculture, and of the agricultural experiment stations of Illinois, Indiana, Iowa, and Kansas. The bulletin supersedes U. S. Department of Agriculture publications 38–Wheat 1, Wheat Storage in the Ever-Normal Granary, May 1938; and G–106, Wheat Storage on the Farm and in the Ever-Normal Granary, June 1941.

The storage of ear corn is discussed in Farmers' Bulletin 2010, Storage of Ear Corn on the Farm.

Loans, purchase agreements, and crop insurance for wheat and other grains are closely related features of the program. Loans and purchase agreements help to hold surplus grains in orderly storage, stabilize prices, and protect farm income when the surplus gets too big; crop insurance protects the grain producer against unavoidable crop losses.

Local administration of the program is carried out by the Production and Marketing Administration through its elected county and community committees of farmers.

STORAGE OF GRAIN UNDER GOVERNMENT LOANS AND FOR GOVERNMENT PURCHASE

The loan program provides that the stored grain shall be collateral for the Government loan. It is essential to the success of the program that only good-quality grain be stored and that it be placed in bins or granaries where it will not be subject to losses in quantity or to damage due to moisture, insects, rodents, or other causes.

Approval of structures and of quality of grain is under the direction of county committees of the Production and Marketing Administration. These committees also are responsible for periodic reinspection of the grain and for requiring fumigation or any other measures that may be necessary to protect the quality of the grain.

Grain that is under purchase agreement also should be stored safely, since the Government will not accept such grain unless it meets the quality specifications for grain under loan.

MEASURES OF ELIGIBILITY FOR LOANS

The quality of grain upon which Government loans will be made is determined by the use of the Official Grain Standards of the United States[2] together with additional requirements as to moisture content and freedom from hidden insect infestation. Not all commercial grades are eligible collateral for loans and limits of moisture content are lower than provided in the standards.

GRAIN MUST BE ACCESSIBLE FOR SAMPLING

When a loan is to be requested, the grain will have to be sampled properly. The grain must be accessible for probing throughout the entire lot, so that a correct and representative sample can be obtained for grading. If the grain is not more than 6 feet deep and there is 2½ feet headroom, there will be no sampling difficulty. If the bin has a greater depth of grain or insufficient headroom, it may be necessary to move enough grain to permit the sampler to probe all portions of the lot.

MOISTURE LIMITS

The most important factors in preservation of grain are moisture content of the grain and temperature. The drier the grain and the lower the temperature, the better the grain will store. Temperature of the grain will depend mostly upon the climate of the region in which the grain is stored. In a cold climate, grain can be stored safely with a higher moisture content than in a warm climate. Atmospheric humidity is another factor, but of minor importance. Dry grain will take up moisture if it is exposed to damp air. In a tight

[2] Handbook of Official Grain Standards of the United States. U. S. Dept. Agr., Prod. and Market. Admin. 1947.

bin, however, only the grain on the surface is exposed to outside air and the bulk of the grain, therefore, will take up only a little moisture from the air under humid conditions.

Grains differ in permissible moisture content. For example, it has been found that oilseeds such as flax and soybeans must be drier than wheat or corn in order to store without damage under the same conditions.

In table 1 the median moisture limits are given for grains to be stored within continental United States for 1 year or longer without loss in market grade. This median limit applies to a climate midway between the best and the worst of the region producing that kind of grain. For example, the climate of Nebraska is median for wheat storage. In a cold location the limit may be 1 to 2 percent above the median; in a warm location the limit should be 1 to 2 percent below the median.

It should be noted that these limits are for preservation of market grade. If it is desired to preserve viability of seed or to prevent slow increase in fat acidity, the moisture limits are 1 to 2 percent lower than those given in the table. The drier the grain the less its susceptibility to insect infestatiton. (See p. 23.)

TABLE 1.—*Median moisture limits for grain to be stored in continental United States for 1 year or longer without loss in market grade*

Kind of grain	Median moisture limit [1] (wet basis)	Kind of grain	Median moisture limit [1] (wet basis)
	Percent		*Percent*
Wheat	13.0	Oats	13.0
Grain sorghum	13.0	Soybeans	11.0
Shelled corn	13.0		

[1] See accompanying text for explanation of "median moisture limit."

Another point that should be emphasized is that these moisture limits are not necessarily the average moisture content of the grain in a bin. If the moisture content is uneven, the wettest grain in the bin should not be above these limits. Also, the larger the quantity of grain to be stored in one mass and the higher its temperature, the more care should be taken to be sure it is dry.

REQUIREMENTS FOR BINS AND GRANARIES

There is a wide variety of building materials, such as steel, lumber, plywood, waterproof wallboard, asphaltic roofing and siding, aluminum, concrete, and building tile, all of which may be used satisfactorily for construction of grain bins provided the structural design is adapted to the building materials that are to be used. It would be impossible in this bulletin to discuss all the building plans, materials, and prefabricated bins that will provide satisfactory grain storage. But the basic requirements can be stated. All bins, regardless of the materials used in their construction, must meet these requirements; otherwise, there may be damage or even a total loss of the grain in storage.

It should be emphasized that the following discussion is based on the assumption that the grain will be dry when placed in storage. Conditioning damp grain is discussed on pages 14 to 20.

The basic requirements of bins for dry grain are that the bin must:

1. Hold the grain without loss of quantity.
2. Exclude rain, snow, and ground moisture.
3. Afford reasonable protection against thieves, rodents,[3] birds, poultry, insects, and objectionable odors.
4. Permit effective fumigation to control insects.
5. Provide reasonable safety from fire and wind damage.

Additional requirements when the grain is to be sealed as security for a Government loan are:

6. Sufficient headroom over the grain for inspection and obtaining probe samples.
7. Construction such that the bin would require forcible breaking to be entered after sealing.

There are, of course, many other features of bin design that are important, although they would not affect the quality of the grain; among them are:

8. Reasonable cost.
9. Permanence and low upkeep expense.
10. Fireproof construction.
11. Convenience of filling and emptying.

Any bin of either new or old construction will provide satisfactory and acceptable storage if it meets the basic requirements above.

LOCATION AND SURROUNDINGS[4]

The bin or granary should be in or near the farmstead as protection against loss by theft. It should be located on a well-drained site and safe from damage by surface water. In no case should bins be located on river or creek bottom land that is subject to floods. On the other hand, steep slopes generally are objectionable because of inconvenience in driving to and from the building, higher cost of foundations, and possibility of foundations being undermined by erosion.

The grain bin should be far enough from other buildings and from stacks of hay or straw to reduce fire hazard. A distance of 50 feet at right angles to prevailing winds is considered reasonable protection, but distances up to 100 feet are better and should be used where possible. The site should be kept free from junk, trash, and weeds, which constitute fire hazards and harbor rats and mice.

BINS IN OTHER BUILDINGS

Location of bins in machine sheds is permissible if the basic requirements listed above are provided. It is best to keep automotive equipment and inflammable materials out of the building during the period of grain storage. Location of bins for long-time storage in buildings where livestock is housed is generally not a good practice. In cold weather when the building is closed, the moisture given off by animals raises the air humidity in the building. Under some conditions, moisture may condense on the roof and drip down on the grain. Grain may absorb objectionable odors if held for a long time in a barn.

The air temperature in cold weather will be a little warmer in a barn than in an outside bin. This might prevent the grain from dropping to a low enough temperature to kill insect infestations. On the other hand, a bin within another building will be better protected from the

[3] See Rat Proofing Buildings and Premises, U. S. Dept. of the Interior, Fish and Wildlife Service, Conservation Bulletin 19. 1942.

[4] Suggestions on building arrangement may be found in U. S. Dept. Agr. Farmers' Bulletin 1132, Planning the Farmstead.

sun, and the grain may not become as warm as in an outside bin during the summer. It is advantageous to hold the grain at as low a temperature as possible both summer and winter.

Bins adjacent to railways and heavily traveled highways are subjected to vibration, which causes the grain to settle. This makes the grain more difficult to fumigate.

PLANS FOR BINS

On page 30 of this bulletin there is a list of grain bin plans that may be obtained from State agricultural extension services. Plans are available from other sources and prefabricated bins that are not included in this list are on the market.

The success of the building will depend not only on the over-all lay-out but also on using the proper sizes of joists, studding, ties, and other structural members and on the proper arrangement and joining of all materials used in the structure. It is advisable to build from a detailed working plan.

MULTIPLE USE

Several of the plans listed on page 30 are suitable for multiple use; that is, the buildings can be used for grain storage and later on, if they are not needed for that purpose, they can be converted to livestock or machinery shelters. The space required for storage of surplus stocks of grain may be large in some years, as in 1949, or small at other times, as in the years from 1944 to 1947. Furthermore, there may be changes from time to time in the crops and livestock produced on a farm. In planning a new building it is desirable, in many cases, to consider the possibility of converting it to use for two or more different purposes (fig. 1).

CONVENIENCE FOR HANDLING GRAIN

Bins may be filled by inside stationary elevator, portable elevator, or hand scooping. The inside elevator is often used in a granary or corncrib with central driveway and overhead bins and in elevator-type storages. Such a building with equipment may cost more per bushel of storage than separate bins and portable elevator.

On a livestock farm where some of the bins may be filled and emptied several times during the year, or where much grain must be dried, the labor saved in handling grain may justify the investment in this type of building, including some hopper-bottom bins. The hopper bottom adds to the cost and reduces the capacity of the bin.

In some cases, part of the driveway can be used for machinery storage during part of the year. The use of the driveway or one of the bins for storing mill feeds or screenings is not advisable. These materials provide a source of insect infestation and may cause serious losses to the binned grain.

Portable elevators may be used to fill either single bins or bins in a granary with driveway. The type of portable elevator commonly used in the Corn Belt will handle threshed or shelled grain or ear corn. Some of them will handle baled hay also. This type of elevator is comparatively heavy to move. A lower cost, lighter weight auger or flight-type elevator for shelled or threshed grain only is used extensively in some areas. Some of these elevators are provided with a swinging auger feed to the elevator hopper by means of which a bin with flat floor can be emptied with a minimum of hand scooping.

Farm elevators cause little damage to grain if manufacturers' instructions are followed for installation and operating speed.

Two types of blower elevators are made for handling grain. With one type, the grain is fed into the air stream on the discharge side of the blower. If conveyor tubes are smooth and turns are long, there is a minimum of grain breakage. With the other type the grain comes in contact with the blower blades and some grain is always broken. This blower should not be used where grain is to be stored for long periods. The presence of broken kernels in stored grain is undesirable, as it promotes insect infestation, mold growth, and increase of fat acidity.

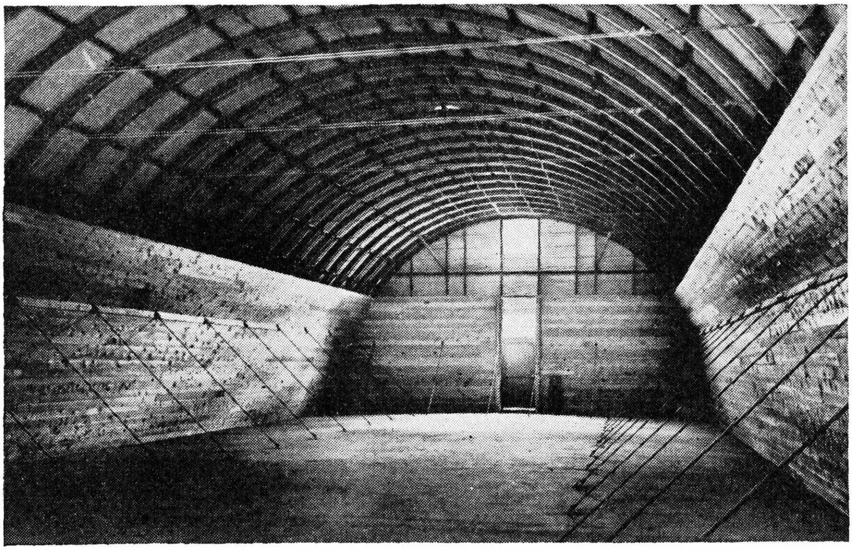

FIGURE 1.—Round-roofed machine shed converted for bulk storage of dry grain. Roof hatches are provided for filling by means of a portable elevator. Wall ties are removable.

Single bins sometimes are provided with filling doors in the gables only. If the building is more than 12 feet long, one or more openings at or near the peak of the roof should be provided. A roof hatch is satisfactory, except that the opening is uncovered when the elevator is placed in position. It is advisable to have a tarpaulin or other cover to protect the grain in case of a sudden shower. A cupola provides better protection during filling but costs more to build.

Usually a bin near ground level should be provided with a walk-in door. This provides an opening for hand scooping and also makes the bin more convenient to use for storing seed or other materials when it is not filled with grain. An additional scoop door at a higher level, but not more than 10 feet from the ground to the bottom of the door, is useful in some cases, particularly with the smaller sizes of bins. Not all farms have elevators, and sometimes it may be necessary to move small quantities of grain that can be scooped by hand with less labor than would be required to set up a portable elevator.

BIN CONSTRUCTION

FOUNDATIONS

The foundation should have footings large enough to prevent damage to the building by uneven settling. One square foot of bearing surface on the ground for each 50 bushels of wheat is satisfactory on most soils. The foundation should extend deep enough in the ground to provide stability and protection against undermining by running water, rodents, or livestock. For a masonry building the foundation should run below the depth to which the ground freezes. Heaving by frost action is not a serious hazard with wood frame or steel bins, since these structures are flexible enough to stand any ordinary amount of distortion by such heaving. For permanent frame bins the foundation should extend a minimum of 18 inches below the ground surface. This minimum should be used only where there will be no washing of the soil away from the foundation.

Foundation should extend above ground level high enough to protect wood from moisture and prevent rats from working under the floor. If a wood floor is used, the lower edge of the floor joists should be at least 12 inches above the ground. A distance of 15 to 18 inches is better. Permanent foundations should be built of masonry, preferably concrete. In a continuous foundation wall, two 3/8-inch or 1/2-inch reinforcing bars, one near the bottom and one near the top, add to the strength and aid in preventing cracking of the concrete.

Semipermanent or temporary foundations of concrete blocks or other materials of equal strength and permanence have been used extensively for small- and medium-sized bins. If the blocks are of good enough quality to withstand dampness and frost action and if enough blocks are used to give sufficient bearing on the soil (one block for each 40 to 50 bushels of grain), these foundations, in general, give satisfactory service (fig. 2). For round steel bins a ring of concrete blocks to support the bin wall, as illustrated in figure 3, has been used extensively and proved satisfactory. The metal floor rests on a dirt or gravel fill inside the ring of blocks. On level ground, a single course of blocks is sufficient; on slopes, two courses are usually needed.

TERMITE PROTECTION

In areas where termites may attack wood in buildings, metal termite shields at the top of foundation walls or other methods of protection should be used.[5]

ANCHORING

Wood or steel bins when empty are not heavy enough to withstand windstorms unless they are firmly anchored to the ground. If the bin is supported on a concrete foundation, bolts should be cast in the concrete to fasten sills to foundation.

If a semipermanent or temporary block foundation is used, the bin should be anchored to "dead men" buried in the ground or by posts set at the wall, as shown in figure 4. Anchoring of round steel bins is of special importance. A great many such bins have been wrecked

[5] See U. S. Dept. Agr. Farmers' Bulletin 1933, Decay and Termite Damage in Houses. March 1948; and Farmers' Bulletin 1911, Preventing Damage to Buildings by Subterranean Termites and Their Control. March 1946.

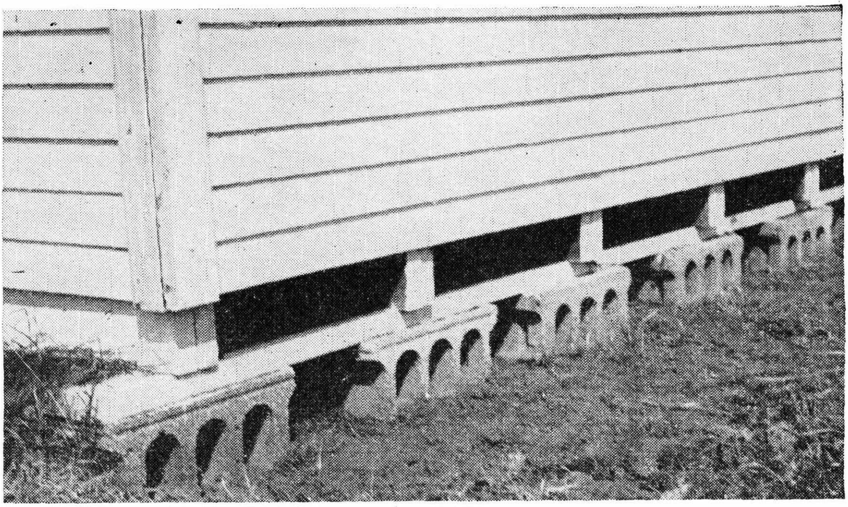

FIGURE 2.—Correct setting of concrete blocks for temporary foundation. Flat sides of blocks are down to give full bearing on ground. Two-inch planks over blocks equalize load. Setting blocks at right angles to joists reduces tipping.

FIGURE 3.—Concrete block foundation for round steel bin. Note No. 9 wire holding blocks in place. Earth or gravel fill is well compacted.

by windstorms that would not have caused any damage if the bins had been properly anchored.

FLOORS

Wood, steel, and concrete floors have been used extensively, and all have given satisfactory service if properly built. A temporary floor of asphalted roll felt roofing with lapped, cemented joints and laid on the ground has been used experimentally and has been successful.

Wood floors should be of tongue-and-groove flooring to prevent any leakage of grain and to prevent any excessive leakage of fumigating

gases. The floor must be supported well above the ground to permit air circulation under the floor and to be safe from damage by rats, as explained above in the discussion of foundations. The space under the floor should be accessible for spraying or dusting to prevent insect breeding in spilled grain.

Floors and joists must not be loaded beyond their weight-carrying capacity. Table 2 shows the depth to which grain may ordinarily be safely stored on wood joists of common sizes with ordinary spans and spacings. In some cases it may be more economical to shorten the span, thus reducing the size of joist necessary, by adding another

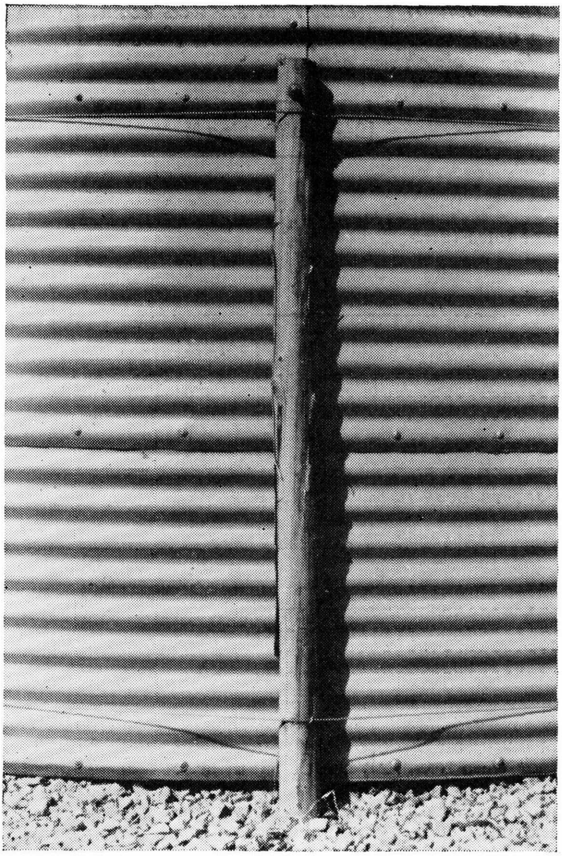

FIGURE 4.—Post anchor for steel bin on crushed-rock foundation. Four treated posts, set 2⅓ to 3 feet in ground and extending 4 feet above, are bolted to bin. Two strands of No. 9 galvanized wire are drawn tight around bin, one near top of post, the other near the bottom.

foundation pier for joist support. A joist that is split near the center is weakened considerably. Similar reduction in strength may be caused by large knots, especially if they are near the lower edge of the joist. Joists with such defects should not be used. Flooring and joists should be inspected carefully for termite damage and decay.

Galvanized sheet-steel floors laid on earth or gravel fill have been used generally in round steel bins. These floors keep rats and mice

out and protect the grain against absorption of moisture from the ground. The floor should be coated on the underside with an asphalt roof paint. If this is not done the floor may rust out while the rest of the building is still good. The principal difficulty experienced with this floor has been infiltration of small amounts of water at the junction of the floor and wall. It is hardly practicable to make this joint absolutely watertight. The difficulty can be averted by providing good drainage away from the lower edge of the steel wall and by placing the floor at a level a little higher than the foundation on which the wall rests.

TABLE 2.—*Safe depth of wheat, rye, shelled corn, grain sorghum, or soybeans* [1] *in bins with joists of common sizes and spans, with 2 and 3 supports, for 24-inch spacings* [2]

JOISTS SUPPORTED AT ENDS ONLY

[24-inch spacing [3]]

Size of joist (inches)	Depth of grain for—			
	6-foot joist	8-foot joist	10-foot joist	12-foot joist
	Feet	*Feet*	*Feet*	*Feet*
2 by 6	3½			
2 by 8	5	3½		
2 by 10	6	4½	3½	
2 by 12	7½	5½	4½	3½

JOISTS SUPPORTED AT EACH END AND AT CENTER

[24-inch spacing [3]]

Size of joist (inches)	6-foot joist	8-foot joist	10-foot joist	12-foot joist
2 by 4	3½			
2 by 6	6	4½	3½	3
2 by 8	8	6	4½	4
2 by 10	10	7½	6	5
2 by 12	12	9	7	6

[1] Depth of oats may be ½ more and of barley ⅓ more than above.

[2] This table is based on the ordinary commercial sizes of lumber. If the joists are full-size rather than nominal, the depth of grain can be increased ⅓. If soft, lightweight lumber such as cottonwood is used, the depth of grain should be reduced ⅓. The joists should be bridged to distribute the load and to prevent twisting and turning.

[3] If joists spacing is 12 inches, grain depth may be doubled.

Concrete floors, in some cases, have given trouble due to dampness. Concrete itself is not moisture-tight and may carry moisture from damp soil up into the grain. Unless the floor rests on exceptionally well-drained and permanently dry soil, a moisture barrier should be used. This may be roll roofing laid on the ground under the concrete (figs. 5 and 6). If a fill of coarse gravel has been used, the surface should be smoothed up with a layer of cement grout under the roll roofing. A method for existing floors is to use roll roofing or hot asphalt over the surface of the floor. This method has the objection that the moisture barrier is subject to mechanical damage when the bin is emptied.

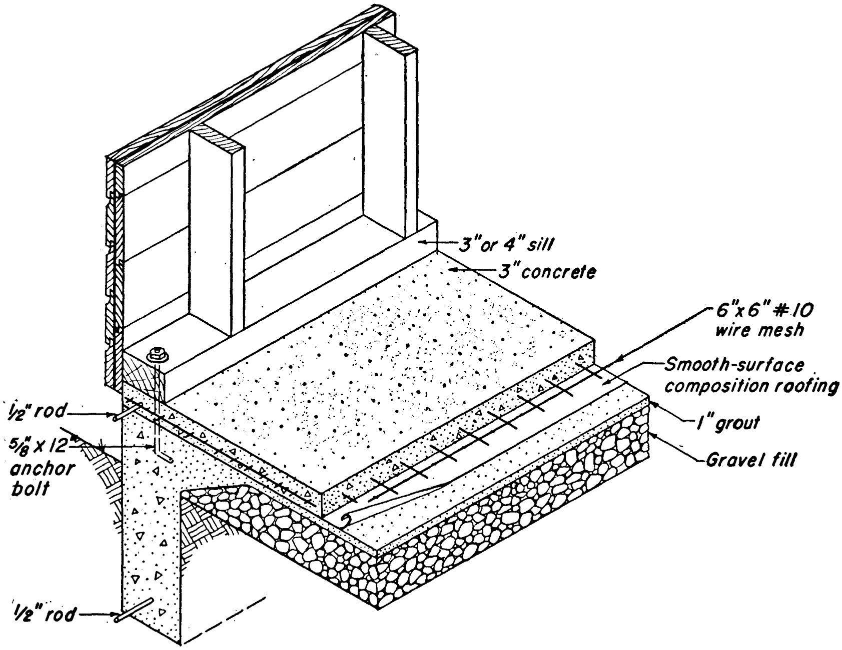

FIGURE 5.—Concrete floor and foundation for wood grain bin, showing composition roofing used as moisture barrier. Note anchor bolts, reinforcing rods, and wire mesh.

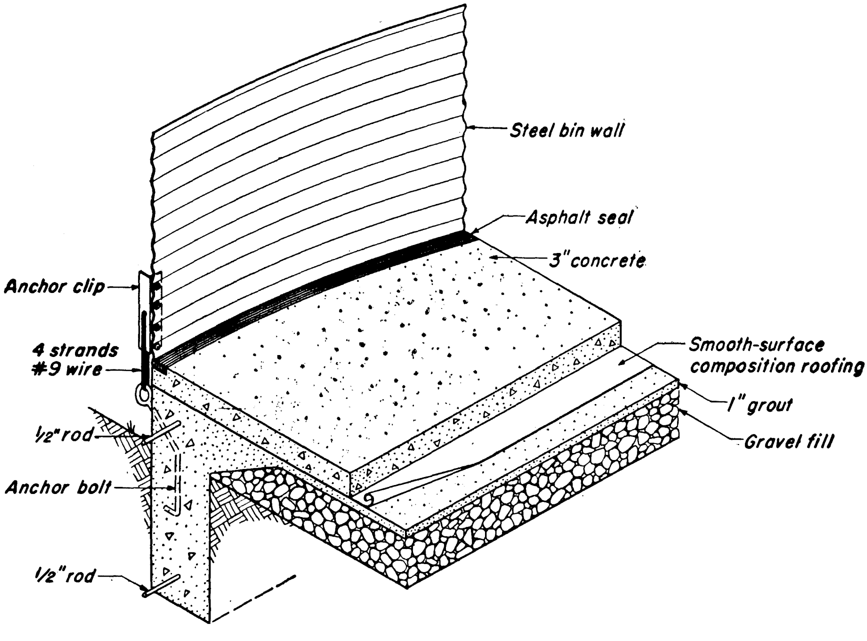

FIGURE 6.—Concrete floor and foundation for steel grain bin. Floor is 1 inch or more above lower edge of bin wall. Note moisture barrier, asphalt seal at wall, and means of anchoring bin to foundation.

Where concrete floors were used experimentally for round steel bins, the principal difficulty was infiltration of water at the floor-wall joint. The finished floor level should be at least an inch above the lower edge of the wall (figs. 5 and 6).

Floors for any type of bin must be high enough above the ground surface to prevent the infiltration of surface water. A minimum of 8 inches above grade is recommended.

WALLS

Grain-bin walls should be constructed to prevent the passage of any moisture through the wall to the grain. Leakage of small amounts of rain water has been a common fault of grain-bin walls.

Walls of grain bins must be strong enough to withstand the lateral pressure of the grain. The size and the spacing of studs affect the strength of the walls. Table 3 shows the safe depths of grain for common sizes and spacing of studs. The bottom of the studs must be securely fastened to the joists or otherwise securely fastened to resist the outward pressure of the grain. When building new storage structures it is best to follow plans that show proper sizes and spacings of anchor bolts, joists, studs, and other features.

In old bins with walls that are too weak to permit being filled to full height, cross ties of wires or rods may be installed. With such tie rods, 4- by 4-inch or larger stays are placed around the outside of the bin, as shown in figure 7. Cross tieings in the form of boards and cross braces often are not satisfactory because they are not fastened securely enough at the ends with nails or common bolts.

TABLE 3.—*Safe depth of wheat, rye, shelled corn, grain, sorghum, or soybeans in bins with studs of common sizes and spacings* [1,2]

Size of studs (inches)	Spacing, center to center	Length of stud	Depth of grain	Size of studs (inches)	Spacing, center to center	Length of stud	Depth of grain
	Inches	*Feet*	*Feet*		*Inches*	*Feet*	*Feet*
2 by 4	24	8	5	2 by 6	24	8	8
2 by 4	16	8	6	2 by 6	16	10	9
2 by 4	12	8	7½	2 by 6	24	10	8

[1] This table is based on the ordinary commercial sizes of lumber. If the studs are full-size rather than nominal, the depth of grain can be increased ⅓. If large knots occur in any of the studs or if the lumber is soft and lightweight, ties should be used across the bin. Studs should be well fastened to the floor system.

[2] Depth of oats may be ½ more and of barley ⅓ more than above.

Wood-Frame Bins

Walls constructed of studding covered with a single layer of drop siding or other dressed and matched lumber have not generally proved to be satisfactory except for short-time storage. It is almost impossible to make such a wall proof against leakage in case of heavy rain driven by a high wind. If the drop siding is fully seasoned and carefully applied, the leakage may be slight and the damage to grain minor, but numerous cases have been observed where water leakage through this type of wall has caused severe damage to the grain.

A single layer of exterior plywood or other waterproof wallboard of sufficient strength applied outside of the studs is satisfactory if the joints are made watertight. Horizontal joints should be lapped at least 2 inches or else made with metal flashing. Vertical joints should be calked and battened. Both horizontal and vertical joints can be made watertight by gluing to frame members when waterproof glue is used by experienced workmen.

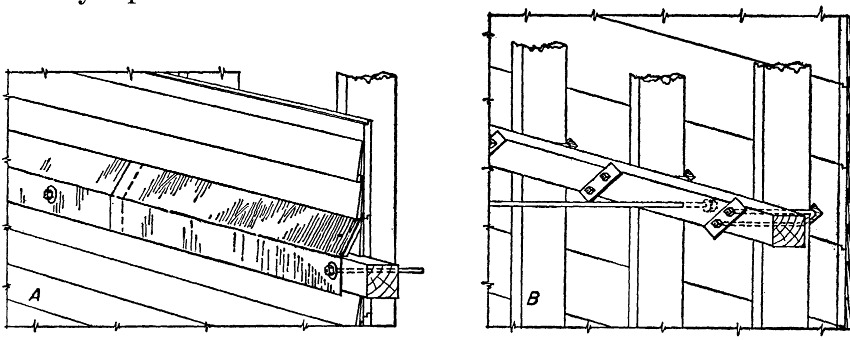

FIGURE 7.—Methods of reinforcing wall for greater depths of grain than shown in table 3: *A*, Exterior stay timber with flashing; *B*, inside stay timber secured to studs with U-bolts, the tie rods extending through the timber.

Preferred construction for wood-frame bins calls for two thicknesses of material outside of the studs with a layer of waterproof paper between and no lining on the inside of the studs (fig. 8). Sheathing may be of shiplap or matched boards, with studs spaced not more than 24 inches on centers, or of interior plywood or other board, with studs spaced closer according to the strength of the material. Sheathing must be well nailed. Lay building paper over the sheathing and cover with one of the following: (1) Horizontal wood or asbestos siding; (2) wood, asphalt, or asbestos shingles (for shingles, use ¾-inch sheathing); (3) galvanized or aluminum sheet metal; or (4) any other equally watertight and serviceable material. The wall covering should, in all cases, extend at least an inch below the top of the foundation.

Steel Bins

Walls of round steel bins made of galvanized steel sheets bolted together generally have not been completely raintight, even with joints calked. Damage from this cause has not been excessive, but still it is sufficient to justify some improvement in construction. The principal points of leakage have been at vertical joints in the wall, at joints of wall sheets to door frames, and at bolts. Leakage at vertical joints and at doorframes possibly could be prevented by use of suitable gaskets. The bolts used in joining wall sheets are intended to be installed with lead washers. Leakage has been due to: (1) Leaving the washer out, (2) not screwing the bolt tight enough, or (3) screwing the bolt too tight and squeezing the lead washer out of position.

ROOFS [6]

It is essential that grain-bin roofs be watertight. Small leaks that might be tolerated in the roof of a corncrib or a livestock shelter may

[6] See U. S. Dept. Agr. Farmers' Bulletin 1751, Roof Coverings for Farm Buildings and Their Repair. 1935.

cause severe damage to shelled or threshed grain stored in a tight bin. Any standard substantial roofing material is acceptable if properly installed and in good condition, but roofs covered with tarred felt or other lightweight materials are not suitable. Special attention is necessary to construction of roof hatches, ventilators, or any other roof openings.

In areas where fine, dry snow may drift into a bin during winter storms, the roof should be as nearly dusttight as practicable. A tight joint of roof to wall should be made. Any ventilators should have means of tight closing during the winter.

Under humid conditions when there may be condensation of moisture on the under side of the roof at times, some provision for ventilation of the space above the grain is desirable. Openings must be designed to keep out rain and should be screened to keep out birds.

DOORS AND OTHER OPENINGS

One of the most frequent causes of damage to grain in wood and steel bins has been leakage of rainwater at doors and other wall and roof openings. Doors in outside walls should be carefully fitted. A drip cap should be used at the top of the door and the door sill should drain to the outside. Roof hatches must be installed with metal flashings to prevent leakage. Roof openings in steel bins have, in some cases, had insufficient strength in the material at the sides of the opening. If these parts are bent out of exact shape, the cover does not fit and rain-water leakage and some grain spoilage results.

METHODS OF CONDITIONING DAMP GRAIN

Grain that is to be stored longer than for a short period in cool weather should have moisture contents not exceeding the limits stated on page 3. Grain should be dried below these limits before shelling, threshing, or combining, but under adverse weather or crop conditions this may not always be possible. When there is a question whether the grain is dry enough, it is best to take samples and get them tested rather than to depend entirely on the appearance and feel of the grain. However, when there is dew at night, ripe grain in the field may be too wet in the morning and evening, although dry enough during the day. The farmer will have to depend, at least partly, on his experience and judgment in deciding how early in the morning and how late in the evening it is safe to operate a combine.

One fact not well understood by many farmers is that one load of damp grain in a bin may heat or mold even though the grain below and above is dry. On Wheat storage research, Kelly et al.[7] state: In tests with combined wheat, where the wheat moisture content was uneven, it was found that the length of safe storage did not depend upon the average moisture content for the bin but upon the highest wheat moisture content in the bin. When it is desired to store grain having a moisture content higher than the limit for safe storage, the following methods of conditioning may be useful.

CLEANING

The removal of weed seeds, broken kernels, chaff, and other foreign material improves the keeping quality of threshed grain. If the

[7] See U. S. Dept. Agr. Cir. 637,Wheat Storage in Experimental Farm-Type Bins. 1942.

grain contains a large amount of green weed seeds or broken bits of green stems, these materials should be removed immediately after threshing to prevent absorption of moisture by the grain. To be effective for this purpose, cleaning must be done within 1 or 2 hours after threshing; therefore, when recleaning is needed, it is desirable to have the recleaner mounted directly on the combine or thresher.

Shelled corn intended for storage should be carefully cleaned at time of shelling. This is of great importance, since corn free from grain dust and broken kernels is unattractive to the insects that cause the greatest damage to corn stored in the commercial corn area. Screens should not be overloaded, particularly when cleaning up under the sheller at the end of the run; otherwise, concentrations of screenings and insects may be carried over with the shelled corn. In the Southern States the cleaning of shelled corn, while desirable, is not so effective in preventing insect damage, owing to the prevalence of field infestation by the rice weevil in that region.

TURNING

Turning grain (moving it from one bin to another) to prevent heating and deterioration is a common practice in terminal and country elevators. This can be done economically where grain can be drawn by gravity from one bin into an elevator pit and elevated to another bin without any hand work. It requires one empty bin. Most farms are not equipped to move grain economically from one bin to another; but this practice has been carried on experimentally in farm-type bins to determine what benefits can be obtained.[8] This study showed that turning does not make any important reduction in the average temperature or the average moisture content of a bin of grain. However, when the moisture content is uneven, turning is often effective in arresting heating and deterioration by mixing the damp grain with the dry grain in the bin.

In grain bins containing "hot spots" due to presence of insect infestation, turning scatters these insects throughout the bin, causing universal infestation of the grain. In such cases it is important that the bin be fumigated immediately after turning.

NATURAL VENTILATION

A large amount of experimental work has been done in testing the storage of damp grain in bins provided with various designs of ventilators that depend upon the wind to force air flow through the bin. It was found that the ventilating system should be designed to force air flow uniformly through all parts of the mass of grain. Air flow from one end to the other of perforated tubes embedded in the grain was not effective unless the tubes were located within a few inches of each other throughout the bin. Other requirements are that ventilators or wall openings must not permit any infiltration of water or snow into the grain during storms, they should not interfere with effective fumigation, and the bin should be adaptable to drying variable quantities of grain. Sometimes a farmer may have only one load of grain that needs drying.

A suitable design of bin for this purpose is shown diagrammatically in figure 9. The cowl at the top of the air tube is designed to face into the wind automatically. Air is blown into the enclosed space

[8] See footnote 7.

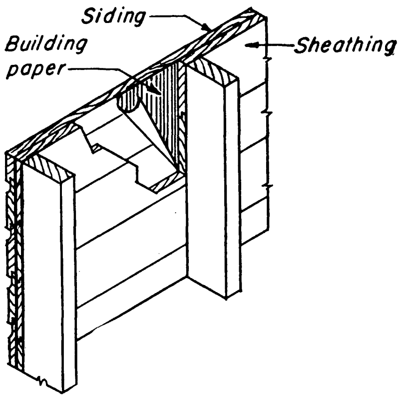

FIGURE 8.—Wall construction for wood frame bin. Wood siding may be replaced by other coverings.

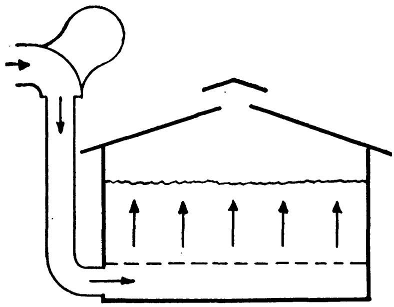

FIGURE 9.—Bin with air chamber under perforated floor, connected with wind-pressure cowl.

under the perforated floor and upward through the grain. The floor construction is the same as shown for drying with power ventilation and heated air (p. 18). A thin layer of grain over the floor will dry faster than a thick layer. The limit of depth for effectively drying grain with 2 to 4 percent excess moisture under conditions at Hays and at Hutchinson, Kans., was found to be about 3 to 6 feet, depending upon the kind of grain and its moisture content.

Drying by this method depends upon atmospheric temperature and humidity. It is recommended only for dry climates. Even there drying may be too slow for safety in the late fall or winter or during periods of unusually high humidity. Drying small lots of damp grain by this method has been beneficial and profitable on a good many farms, but with electric or gasoline engine power available now on most farms, drying by power ventilation is generally a better method because of better reliability and larger drying capacity for a given size of drying bin.

POWER VENTILATION WITH UNHEATED AIR

A bin floor suitable for this purpose is shown on page 18. Air is forced by power-driven fan into the enclosed space under the perforated floor. From there it flows upward through the grain.

No rigid requirements can be stated as to rate of air flow and depth of grain to be dried in a batch. Air flow of 3 c. f. m. (cubic feet per minute) per bushel of grain and a depth of from 3 to 6 feet of grain generally would result in economical drying. Power required to operate the fan and maintain the same rate of air flow per bushel increases greatly with increased depth. See discussion on pages 19 and 20. A higher rate of air flow per bushel will dry the grain faster, but it increases the power requirement for the same depth of grain. A rate of 5 c. f. m. per bushel with grain depth of 3 or 4 feet would be better for very damp grain.

Drying by power ventilation with unheated air, like drying by natural ventilation, depends upon atmospheric temperature and humidity, but the positive, higher rate of air flow obtained by power ventilation is a big advantage.

Heating grain can be cooled to within a few degrees of atmospheric temperature by about 6 hours of power ventilation at any time, summer or winter, using air flow of 3 c. f. m. per bushel. Drying will be very slow in the winter or during periods of high humidity in the summer. In warm, dry summer weather, grain moisture content sometimes may be reduced 2 percent in 24 to 48 hours of operation, but usually a longer period will be necessary.

Drying is more rapid during the day than at night. The fan may well be started at 9 or 10 o'clock in the forenoon on clear days and operated until 7 to 9 o'clock in the evening.

DRYING BY POWER VENTILATION WITH HEATED AIR [9]

This method of drying has the important advantage that it can be done promptly at any season of the year and regardless of weather conditions. It has been used for many years by terminal elevators and more recently by a good many local elevators. Hybrid seed corn producers generally dry the seed by this method. In the last few years a good deal of research work has been done to develop methods and equipment for drying grain on the farm. There are now a number of portable, forced-air heating units on the market that are suitable for use on farms. Each unit consists of a power-driven fan and an oil burner or other heater for warming the air, with suitable safety controls. This equipment is usually mounted on a rubber-tired trailer for convenience in moving.

FIRE HAZARD

There is bound to be some fire hazard when fuel is burned to heat air for drying. Fires are likely to result from the use of badly designed equipment, inadequate safety controls, or careless operation. With the right kind of equipment, the hazard should be little, if any, more than in burning fuel in a house furnace. If the drying is done in a fire-safe structure such as a steel bin, with well-designed drying equipment and with care in handling fuel, fire hazard need not be a serious obstacle to this method of conditioning grain.

BATCH V. CONTINUOUS-FLOW DRYING

Grain can be dried in a continuous-flow structure, as used by some elevators, or in batches, as when the grain is dried in a bin. A bin equipped for this purpose is shown in figure 10 and in plan No. 5724 (p. 30). Continuous-flow drying structures have been developed for drying rice on farms but so far have not been used extensively for drying other grains on the farm. Plans 5532 and 5710 are suitable for use with continuous driers.

The following discussion applies particularly to batch or bin drying.

DRYING TEMPERATURE

Drying will not necessarily be any more economical at high than at low temperatures even though the rate of drying may be increased.

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[9] Information on grain drying also may be available from the State agricultural experiment stations. The following articles may also be consulted:

Hukill, W. V., Basic Principles in Drying Corn and Grain Sorghum. Agr. Engin. 28: [335]–338, 340. 1947;

Hukill, W. V., Types and Performance of Farm Grain Driers. Agr. Engin. 29: [53]–54, 59. 1948;

Shedd, C. K., Mechanical Drying of Corn on the Farm. U. S. Dept. Agr., Bur. Plant Indus., Soils, and Agr. Engin. Processed Pub. 1948.

Drying at temperatures above 130° F. causes some changes in chemical structure of the grain that are undesirable if the grain is to be milled. It is recommended that air temperatures in farm driers be kept below this limit. A limit of about 110° is considered necessary if the grain is to be used for seed.

In a bin drier the bottom layers, where the air enters, will dry first and the top layers last, the difference in amount and rate of drying depending on the humidity, temperature, and volume of drying air. With the drying air heated to between 10° and 25° F. above atmospheric temperature, the relative humidity of the heated air will usually be between 30 and 60 percent. In this range none of the grain will be dried below about 10 to 12 percent moisture. Drying will be slow, especially so in cold weather, but eventually all the grain can be dried to a relatively uniform moisture content of 10 to 12 percent.

If the temperature is raised to say 70 degrees above atmospheric temperature, the bottom layers of grain will be dried to as low as 5 or 6 percent moisture, possibly before the upper layers dry at all. The drying will progress upward and eventually all the grain can be dried to a uniform moisture content of 5 to 6 percent. Usually, it will be desirable to stop the drying when the average moisture content of the grain is about 15 percent for short-time winter storage or 10 to 13 percent for warm weather or long-time storage. (See table 1, p. 3.) The bottom layer of grain may then have dried to 5 to 6 percent moisture while the top layer may have dried very little.

Continued ventilation of the grain after the heater is shut off will cool the grain and partially equalize the moisture content in the various layers, but the top layers may still be too wet for safe storage.

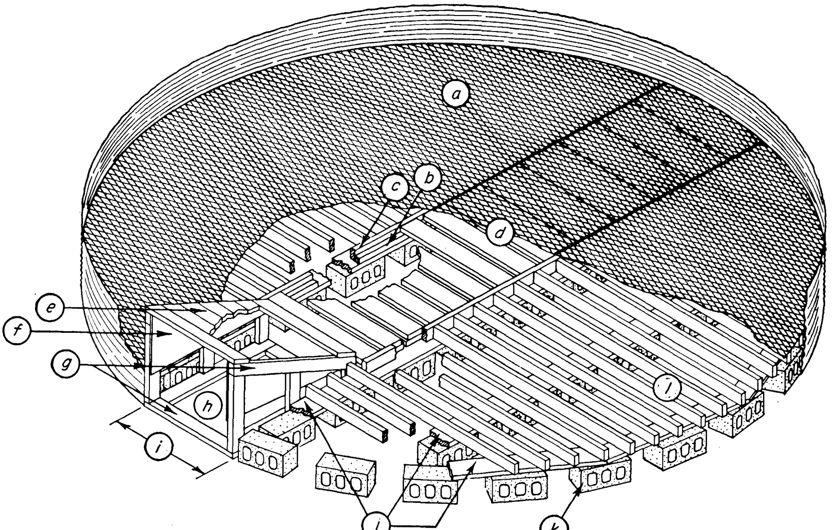

FIGURE 10.—Perforated floor for drying small grain or shelled corn: *a*, Perforated sheet metal, or expanded metal rolled flat, or hardware cloth covered with screen of size to hold grain; *b* and *c*, wood 2 by 2 and 2 by 4; *d*, 2 by 8's spaced 3 inches and covered with 18- by 42-inch sheets; *e*, 2 by 8 duct-cover planks; *f*, ¼-inch plywood extending below floor; *g*, 2 by 4 frame of duct; *h*, air duct, 32 inches high at door; *i*, width of door; *j*, 2 by 8 wood sills; *k*, 8- by 8- by 16-inch concrete blocks, 8 inches apart; *l*, 2 by 4 joists, 8 inches on centers.

Except for a short period of storage, it will be desirable to mix the grain by moving it to another bin, if it has been dried with a temperature rise of more than 25° F.

The advantage of the low temperature rise is the resulting uniform moisture which will make the grain safe for storage without mixing. The advantages of using a higher temperature rise are that the drying can be completed in a shorter time and the total power cost for driving the air through the grain will be less.

Table 4 shows the total drying time, the amount of heat required, and the final range in moisture content as computed for bin drying of shelled corn under two atmospheric conditions, two rates of air flow, and two drying air temperatures. In these examples the initial moisture content is taken as 20 percent and the corn is dried until the average moisture is 13 percent. Other grains will dry at somewhat faster or slower rates, but the comparative effects of different temperatures and humidities will be much the same as with shelled corn.

TABLE 4.—*Total drying time, amount of heat required, and final range in moisture content, as computed for bin drying of shelled corn from 20 percent initial moisture to average of 13 percent final moisture under 2 atmospheric conditions, 2 rates of air flow, and 2 temperature rises*

Temperature	Air flow 4 cubic feet per minute to the bushel [1]			Air flow 10 cubic feet per minute to the bushel [1]		
	Drying time	Heat required	Final moisture range	Drying time	Heat required	Final moisture range
ATMOSPHERIC TEMPERATURE 30° F.; RELATIVE HUMIDITY 70 PERCENT						
	Hr.	*B. t. u./bu.* [2]	*Percent*	*Hr.*	*B. t. u./bu.* [2]	*Percent*
50° F. air (20° F. rise)	116	10, 750	9. 0–19. 0	52	12, 100	11. 5–16. 7
100° F. air (70° F. rise)	31	9, 920	4. 7–20. 0	13	10, 600	7. 0–18. 2
ATMOSPHERIC TEMPERATURE 50° F.; RELATIVE HUMIDITY 70 PERCENT						
70° F. air (20° F. rise)	81	7, 210	9. 2–19. 7	38	8, 400	10. 4–16. 7
120° F. air (70° F. rise)	26	8, 070	5. 0–20. 0	11	8, 100	6. 2–19. 7

[1] Cubic feet of air per minute per bushel of corn.

[2] British thermal units per bushel of corn. 1 B. t. u. is amount of heat required to raise temperature of 1 pound of water 1° F.

DEPTH OF GRAIN AND RATE OF AIR FLOW

There is a considerable difference in the resistance of different grains to air flow. For example, air pressure of 1.6 inches will force air flow of 10 cubic feet per minute per bushel through the following depths of various grains: Corn, 48 inches; wheat, 31 inches; barley,

38 inches; grain sorghum, 38 inches; oats, 37 inches; rough rice, 35 inches; soybeans, 58 inches.

Drying has been done in a bin with a depth of as much as 10 feet of shelled corn. Even greater depths could be dried. However, in order to maintain the same rate of air flow per bushel (and therefore the same rate of drying) in a deep as in a shallow bin, the amount of air must be increased in proportion to the depth of grain. The air pressure and power required vary with depth of grain and volume of air per bushel, as shown in table 5.

Obviously it is uneconomical to force large volumes of air through deep layers of grain; usually it will be more economical to dry a depth of not over 4 to 6 feet of shelled corn or soybeans or somewhat shallower depths of other grains. There is no definite upper limit of pressure or depth, provided a suitable blower is used, but if the pressure required is over 2 or 3 inches the power requirement is likely to be excessive. Most of the farm drying units now on the market do not develop pressures of more than about 2 inches of water.

TABLE 5.—*Pressure (inches of water) required to force air through shelled corn*

Depth of corn (feet)	For supplying 4 cubic feet per minute per bu.		For supplying 10 cubic feet per minute per bu.	
	Pressure required	Power required per 1,000 bu.	Pressure required	Power required per 1,000 bu.
	Inches	*Horsepower*	*Inches*	*Horsepower*
2	0. 045	¾	0. 20	2
4	. 40	1	1. 6	4
8	2. 3	3	9. 0	27

Examination of tables 4 and 5 indicates that choice of an optimum rate of air flow depends on which factors are most important to the operator. In general, higher rates of air flow shorten the drying time, increase the total fuel requirement, and improve the uniformity of drying. In the examples in table 4 the drying time is reduced to less than half by increasing the rate of air flow from 4 up to 10 c. f. m. per bushel and the total fuel requirement is increased only slightly. At the same time, higher rates of air flow increase the requirement for fan power. In most cases drying will be done economically by air flow of 4 to 10 c. f. m. per bushel.

PROTECTING FARM-STORAGE GRAIN FROM DAMAGE BY INSECTS

Losses of farm-stored grain through insect attack are due chiefly to inadequate storage structures, improper condition of grain at time of storage, failure to clean and spray bins and to remove residues of old grain and feed that have accumulated around bins, inadequate inspection, and failure to fumigate efficiently or at the proper time.

The problem of conserving stored grain from the attack of insects varies in different parts of the United States. In the southern portion of the grain-growing region, insect problems are more acute than in the Canadian-border States, where the temperature of farm-stored grain rarely rises high enough to support insect development (fig. 11).

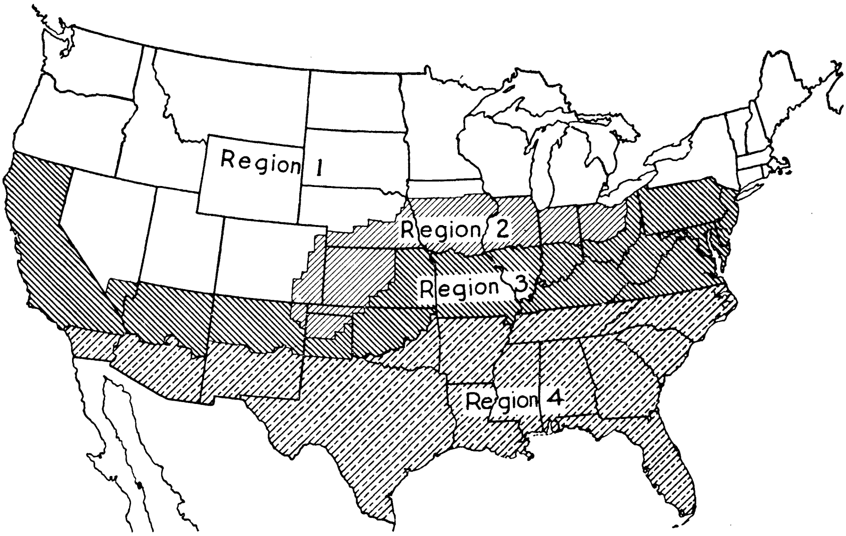

FIGURE 11.—Regional map of the United States, indicating relative hazards to farm-stored grain from insect attack: Region 1, little if any insect damage occurs to wheat stored on the farm during the first season; region 2, insects are troublesome during the first season in some years—frequent inspection and occasional fumigation are necessary; region 3, insects are troublesome every year—frequent inspection and fumigation are necessary; region 4, insect control difficult—special precautions are required if grain is to be stored safely.

INSECT PESTS OF STORED WHEAT, BARLEY, OATS, RYE, AND GRAIN SORGHUM

In the Great Plains region, seven species constitute more than 90 percent of the insect population of small grains in farm storage. They are the flat grain beetle (fig. 12), the saw-toothed grain beetle (fig. 13), the lesser grain borer (fig. 14), the red flour beetle, the long-headed flour beetle, the cadelle (fig. 15), and the rice weevil (fig. 16). The abundance of these insects varies with climatic conditions. In the northern parts of the region the flat grain beetle and saw-toothed grain beetle are predominant, whereas in the southern part the lesser grain borer and rice weevil are more abundant. Along the eastern seaboard the Angoumois grain moth is occasionally one of the common pests of stored grain, and often begins to infest grain in the field before it is harvested. Sometimes the granary weevil is troublesome in farm-stored grain in the more northern States, but because it cannot fly it is not so abundant as the rice weevil.

SPECIES MOST ABUNDANT IN SHELLED CORN

In the commercial corn area—Illinois, Iowa, Nebraska, Minnesota, and South Dakota—six species have constituted 98 percent of the insect

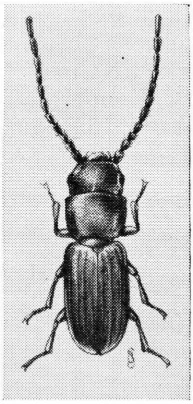

FIGURE 12.—The flat grain beetle. (×17.)

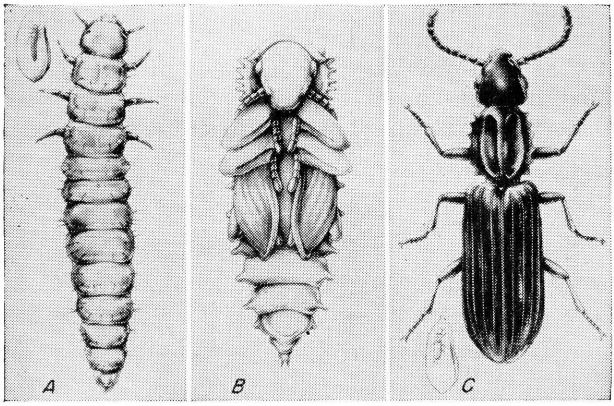

FIGURE 13.—The saw-toothed grain beetle, a frequent inhabitant of stored grain: *A*, well-grown larva; *B*, pupa; *C*, adult beetle. (All ×16.)

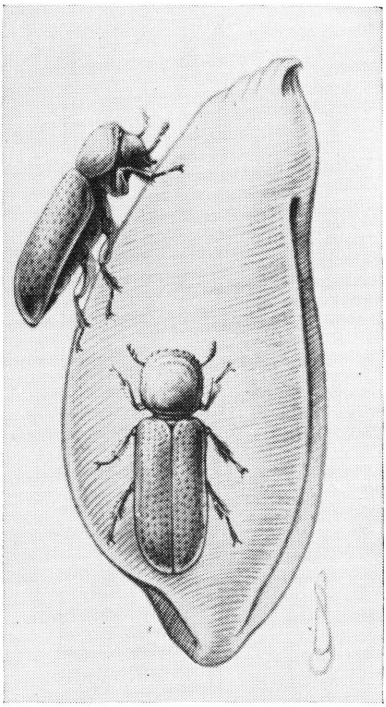

FIGURE 14.—Adults of the lesser grain borer on grain of wheat. (×10.)

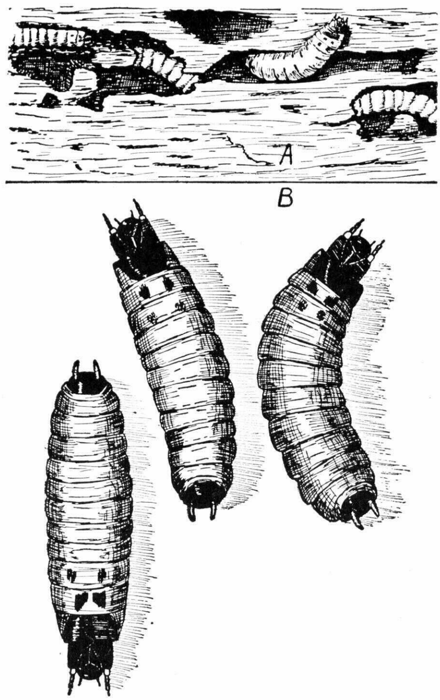

FIGURE 15.—Hibernation of the cadelle: *A*, Sectioned softwood board from granary used for wheat storage, showing numerous larvae using the board for a place in which to rest and pupate (×1); *B*, cadelle larvae about to pupate (×2).

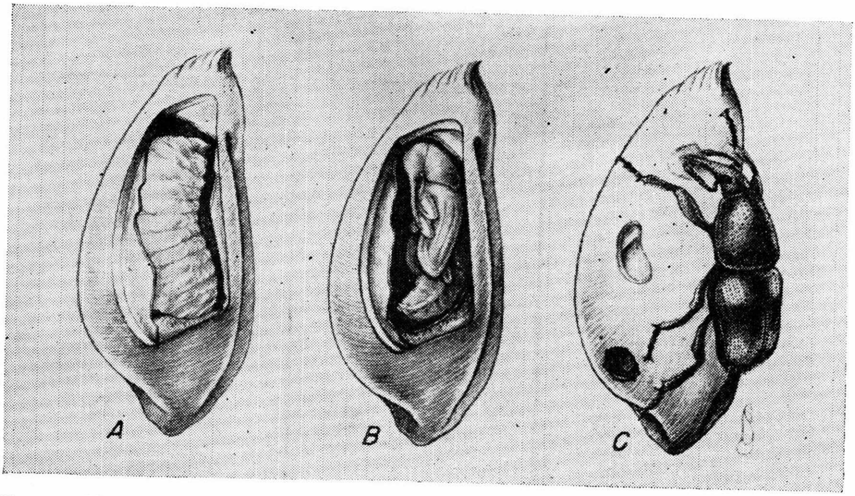

FIGURE 16.—Life stages of the rice, or black, weevil in wheat: *A*, well-grown larvae; *B*, pupa; *C*, adult feeding upon kernel. Note in *C* the hole in lower portion of kernel made by the adult on leaving the seed and at two points higher up shallow holes made by the adult in feeding upon the seed after emergence. (×10.)

population in stored shelled corn, the saw-toothed grain beetle, flat grain beetle, red flour beetle, foreign grain beetle, hairy fungus beetle, and large black flour beetle. The first three of these have been the most important. These insects thrive in corn that contains grain dust and broken kernels. The rice weevil, granary weevil, and lesser grain borer are not common in shelled corn in this area. The Indian-meal moth is occasionally very abundant.

FACTORS INFLUENCING INSECT ABUNDANCE

Grain that is cool, dry, and clean is unfavorable for the development of insects. Bran beetles, such as the red flour beetle and saw-toothed grain beetle, do not lay eggs at 60° F. or below. They do not breed in clean grain unless the moisture content is 11 percent or above or the temperature is 80° or above. If the grain contains floury dust or broken kernels and if the temperature is 70° or above, they will breed in it regardless of the moisture content.

The rice weevil and granary weevil breed freely in clean grain, but only at favorable moisture and temperature levels. Both species will lay a few eggs at 60° F. Immature stages will complete their development at that temperature, although much more slowly than at higher temperatures. The adults of the granary weevil become dormant at 35° and those of the rice weevil at 45°, and they die if exposed to these temperatures for a few weeks. Neither species lives long or breeds in wheat with a moisture content of less than 9 percent, and little breeding occurs when the moisture content is below 11 percent unless the temperature is 85° to 90°.

Insect activities often cause hot spots in the grain in addition to the damage caused by their feeding. With the arrival of cold fall weather,

water vapor condenses in the cooled surface grain as a result of its normal upward movement from the warm to the cool grain. This vapor transfer may be accelerated enough by insect activity that rotting and spoilage of the surface grain may occur.

In regions 1, 2, and 3 the natural cooling of grain in the fall and winter, together with its insulating properties, prevent a rapid rise in the temperature of the bulk grain in the following spring. In the North the average temperature of the bulk of dry grain rarely reaches the 70° F. level favorable for active insect development.

METHODS OF PREVENTING INSECT DAMAGE

Preventive measures are most important in protecting grain from insect damage. Clean, insect-free, weatherproof storage should be provided on the farm, and nearby sources of insect infestation (fig. 17) should be eliminated. It is difficult for these insects to establish and maintain themselves in premises that are always clean and free from accumulations of grain, dust, and debris. Steel bins that are easy to clean and can be made tight by calking are best for farm storage of small grains or shelled corn.

FIGURE 17.—Bags of old feed or screenings stored near bins and accumulations of waste grain and feed on the floor around bins serve as sources of infestation to farm-stored grain and should be disposed of before the bins are filled.

Residual Sprays

Wooden bins should be thoroughly cleaned and before they are refilled the walls and floors should be treated with a residual spray. This will kill most of the insects that emerge from burrows and cracks in the woodwork. Steel bins should also be thoroughly cleaned, and, although it is not necessary to spray the entire bin, it is advisable to spray around the doorframe where insects may be concealed.

Sprays that have been found satisfactory for treating bins consist of 2.5 percent by weight of DDT, TDE, methoxychlor, or chlordane as emulsions or water suspensions, or an emulsion containing 1 percent

by weight of piperonyl butoxide and 0.1 percent of pyrethrins. The sprays should be applied at the rate of 2 gallons per 1,000 square feet of surface area. They can be safely and easily applied with an ordinary garden sprayer, as shown in figure 18.

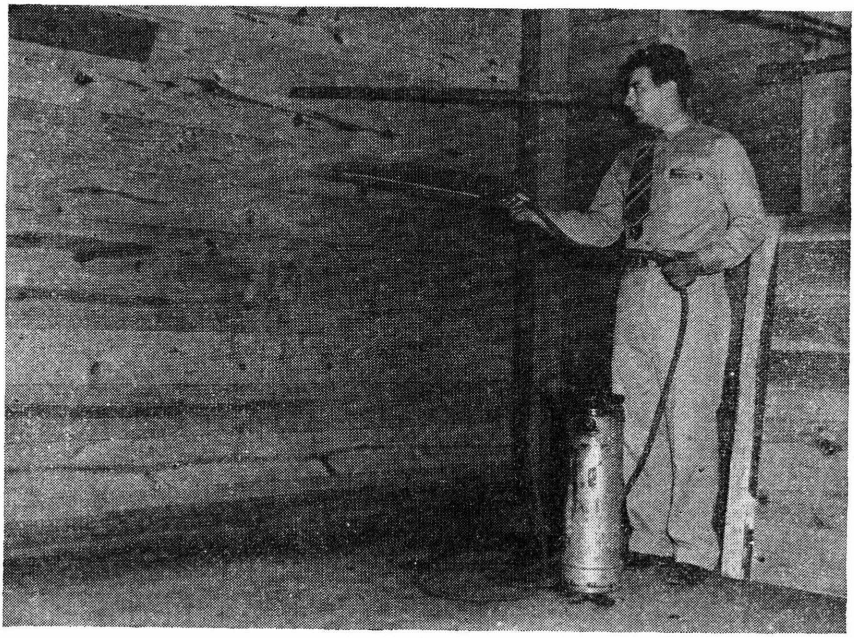

FIGURE 18.—Residual sprays can be easily applied with an ordinary garden sprayer.

In Wheat, Barley, Oats, and Grain Sorghum

Prompt harvesting.—In regions where field infestation by the Angoumois grain moth occurs, prompt harvesting of grain is essential. Prompt harvesting helps to prevent infestation by the grain moth in the bin as well as in the field, since the soft-bodied moths are unable to make their way below the surface of binned grain to lay their eggs. Where combine harvesters are used, damage to grain from this insect is practically eliminated.

Storage.—Grain should be stored as dry as possible. Damp grain attracts insects.

Fumigation.—Farm-stored small grain should be fumigated within 6 weeks after it is placed in the bin in regions 2 and 3, and within 2 weeks in region 4. In region 1 fumigation after storage may not be necessary, but it is good insurance against infestation.

In regions 1, 2, and 3 one fumigation will probably be sufficient. If properly applied, the fumigant will destroy insect infestations present and will protect the grain from serious insect invasion until fall. Winter weather will cool the grain to levels where insects are inactive. Fumigants and dosages recommended for small grains stored in wooden bins are given in table 6.

TABLE 6.—*Fumigants and dosages for the treatment of grain stored in wood bins* [1]

Fumigant	Dosage (per 1,000 bushels)		
	Small grains except sorghums	Sorghum	Corn
	Gallons	*Gallons*	*Gallons*
Carbon tetrachloride	5	8	6
Carbon tetrachloride—			
4 parts, plus carbon disulfide 1 part	3	8	6
1 part, plus ethylene dichloride 3 parts	6	10	6
19 parts, plus ethylene dibromide 1 part	3	8	--------

[1] In steel bins the dosages may be reduced by 50 percent for small grains and about 20 percent for corn and grain sorghum.

With the exception of carbon tetrachloride and the 3:1 mixture of ethylene dichloride and carbon tetrachloride, the fumigants listed may reduce germination if grain moisture is above 12 percent or exposures are excessive.

Periodic inspection.—Farm-stored grain should be inspected periodically to detect dangerous insect infestation, and fumigated whenever such conditions are found. In regions 1, 2, and 3 during the warmer months and in region 4 throughout the year, grain that has been in storage a month or more should be inspected every 2 to 4 weeks.

Infestation is usually found in the top half of the bin when grain temperatures are above 70° F., and the sifting of samples of surface grain will often serve to determine whether or not serious infestations are present. During the winter infestations are likely to be nearer the center of the bin. Grain probes and troughs into which to empty them are needed for obtaining representative samples from the interior of the mass of grain. Two pans are used for sifting the insects out of the samples, in one of which the bottom is replaced with 10-mesh wire screening.

The temperature of the grain is often a good index of its condition. To estimate grain temperatures insert a piece of steel piping or a hoe handle into the grain in farm bins and then withdraw the object and touch it with the hand; or, insert an arm into a shallow bin.

The need for action will depend upon circumstances and the insect involved. In general, if living specimens of the rice weevil, granary weevil, or lesser grain borer are present or, in their absence, if there are sufficient bran beetles present to grade weevily (5 beetles per quart), the situation calls for immediate application of control measures. Similarly, a surface infestation of moths as indicated by the presence of webbing is dangerous. The grain involved should be kept under observation to see that no important changes occur.

Small grains to be stored for a second year or longer should be fumigated annually in mid-August.

In Rough Rice

Rice is commonly infested in the field by the rice weevil and other insects. Hence it must be fumigated as soon as possible after it is placed in storage, with the fumigants and dosages given in table 6. After fumigation it should be protected from insect damage by the same methods recommended for wheat or other small grains.

In Soybeans

Soybeans stored in farm-type bins rarely become seriously infested with insects. Occasionally small infestations of bran beetles may occur in high-moisture beans. If serious infestation should develop, the beans can be fumigated in the same manner and with the same dosages recommended for small grains.

In Corn

Corn can be stored for years in regions, 1, 2, and 3 without appreciable deterioration or loss from insect attack, provided the requirements for safe storage are observed. Except in the southern portion of region 4 field infestation of corn is light. Exposure of the ears in slat bins to the low winter temperature normally reduces infestations to a point where loss from insect attack is inconsequential if the corn is to be used for feed during the ensuing season. After a series of warm winters field infestation of corn by the Angoumois grain moth and to some extent by the rice weevil may occur as far north as the southern portion of region 3.

Slatted-crib bins afford no protection to corn from insects. In the summer, therefore, a certain amount of infestation of ear corn is likely to develop.

Corn that is to be stored for an additional year or longer should be shelled as soon as the moisture content of the kernels is down to a point as low as it is likely to go. In most seasons this will be about the middle of May. Shelled corn with a moisture content higher than 13 percent should not be stored for such periods. The corn should be carefully cleaned, and by use of the proper machinery should be placed in clean, tight bins with the least possible breakage of the kernels. With good cleaning equipment and properly designed elevators, corn can be placed in storage with less than 0.5 percent of cracked kernels. Cleaning is of great importance, since corn free from grain dust and broken kernels is unattractive to the insects that cause the greatest damage. Care should be taken to prevent overloading the cleaning screens when cleaning up under the shellers at the end of the run.

Corn grown in the Southern States is subject to field infestation by the rice weevil and other insects. This corn should be harvested as early as possible after maturity and dried, shelled, and cleaned before it is placed in the bin. It should be stored in tight bins and fumigated immediately. Thereafter, it can be handled in the same manner recommended for shelled corn stored in other regions.

Protective oil sprays.—Spraying the surface of binned shelled corn with oil at the rate of 2 quarts per 100 square feet of surface is an

excellent preventive measure against infestation by insects that are likely to migrate to the bins during the summer. Use a refined white oil of 100 to 200 seconds viscosity (Saybolt) at 100° F., which is free from objectionable odor.

Fumigation of shelled corn.—In the commercial corn area an August fumigation of shelled corn in tight bins will, if properly done, control insect infestations, so that the corn can enter the fall and winter in good condition. The corn will then be ready to undergo the natural cooling of winter so necessary for its protection from insect damage during the following spring and summer. Dosages of fumigants found satisfactory for treating corn in wood and steel bins given in table 6 and footnote.

Periodic inspection.—In all areas stored shelled corn should be inspected at least once a month during periods when the temperature goes above 70° F. When true grain weevils or bran beetles are found, the corn should be fumigated.

FUMIGATION OF GRAIN

For successful fumigation it is necessary to create and maintain a uniform distribution of a poisonous gas throughout the mass of grain long enough to kill the free-living insects and their immature stages within the kernels. Most farm bins are loosely constructed and open at the top. All cracks and openings must therefore be closed by nailing or tacking slats or heavy paper over them to prevent rapid escape of the fumigant. Since strong winds and high temperatures also accelerate evaporation and loss of fumigant, applications should be made in the cool part of the day, when the air is quiet. Covering the grain with tarpaulins helps to retain the fumigant, although this is not necessary. The surface of the grain should be level and at least 6 inches below the top of the bin.

If possible the fumigant should be applied from outside the bin by means of a bucket pump or other type of sprayer (fig. 19), and should be distributed uniformly over the surface grain.

Caution: It is unwise to attempt to apply the fumigant with a sprinkling can, because the vapors have an anesthetic action when breathed. Workers exposed to the vapors for any appreciable period are likely to be made seriously ill. The operator should avoid inhaling any of the vapors, even those from light concentrations, and should also avoid spilling the fumigant on the skin, clothing, or shoes. Wearing apparel wet with the fumigant should be removed at once and the skin washed with soap and water.

A gas mask with a full facepiece and a black canister approved by the United States Bureau of Mines should be used for protection against the fumigants recommended herein and should always be worn by a person who is exposed to the concentrated vapors for more than a very brief period. Gas masks of this type will not afford sufficient protection to persons entering the top of a closed bin to apply fumigant to the surface of the grain. The effective life of a gas mask canister is limited. It should therefore be replaced by a fresh one after 30 minutes continuous or intermittent exposure to grain fumigants, and the length of such exposures should be recorded on the canister.

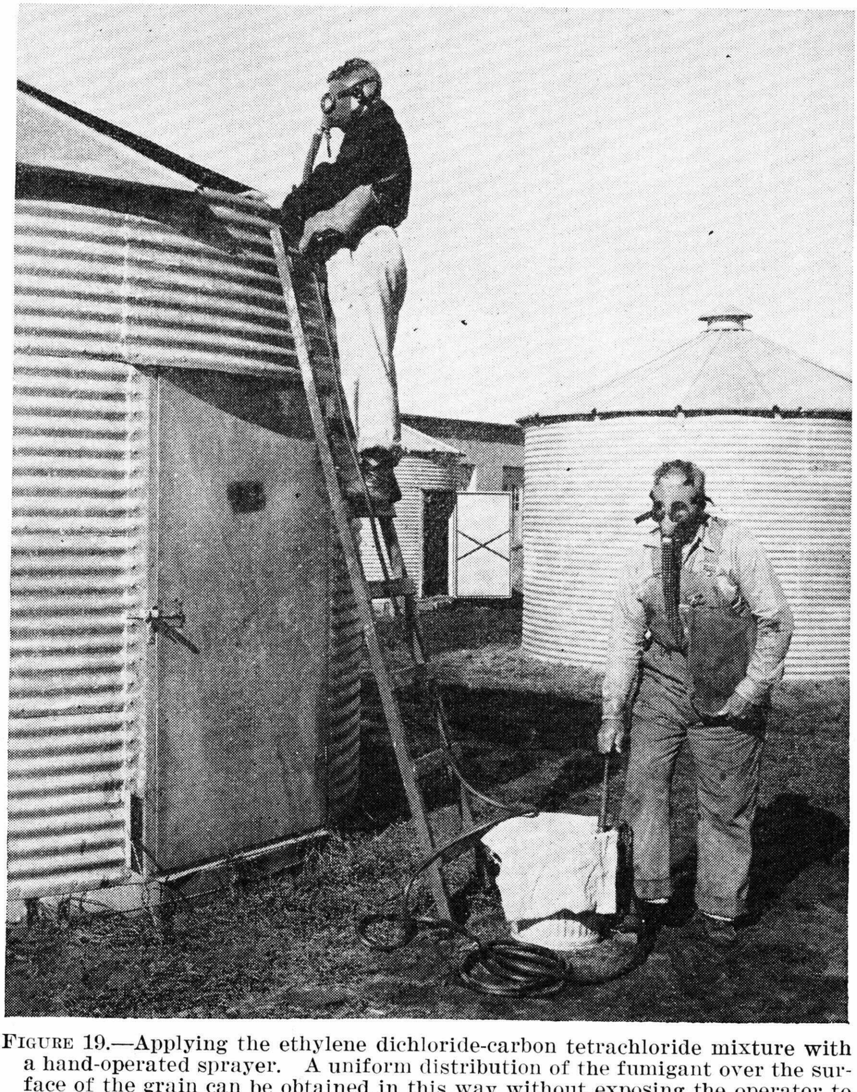

FIGURE 19.—Applying the ethylene dichloride-carbon tetrachloride mixture with a hand-operated sprayer. A uniform distribution of the fumigant over the surface of the grain can be obtained in this way without exposing the operator to strong concentrations of the gas.

GRAIN STORAGE PLANS

The following plans have been prepared by the U. S. Department of Agriculture in cooperation with State agricultural experiment stations of the North Central States. An illustrated catalog containing these and other plans, issued by the Midwest Plan Service, may be consulted at the offices of many county agricultural agents and material dealers. Detailed working plans may be obtained for a small charge through the State extension agricultural engineer. In some States these drawings may be obtained only through county agents. Do not order from the U. S. Dept. of Agriculture.

U. S. D. A. Plan No.	*Description*	*Midwest Plan No.*
	Farm-built grain bins:	
5700	600-bu. movable grain bin. 10′ x 10′, 8′ stud	73251
5701	1,000-bu. movable grain bin. 12′ x 14′, 8′ stud	73252
5702	300-bu. movable hog feeder. 10′ x 16′, with protected feeding floor	77613
5703	400-bu. movable hog feeder. 8′ x 12′, 7′ stud	77614
5704	1,500-bu. grain bin convertible to single-car garage. 12′ x 20′, 8′ stud	73261
5705	2,500-bu. grain bin convertible to double garage. 20′ x 20′, 8′ stud	73263
5706	4,500-bu. grain bin convertible to double-truck garage or shop. 24′ x 24′, 10′ stud	74132
5707	3,400-bu. grain bin convertible to farrowing house. 22′ x 24′, 8′ stud	72627
5708	1,700-bu. four-bin granary. 16′ x 24′, 8′ stud. Seed-cleaning space	73262
5709	8,000-bu. granary. 31′ x 40′. Four bins 10′ x 20′, 11′ driveway, overhead bins	73264
5710	Farm elevator, 10,000-bu. capacity, stud construction. Facilities for cleaning and grinding	73268
5711	Suggested drier lay-out for 5710 and 5532	-----
5532	Same as 5710, except crib construction	73269
5729	500-bu. grain bin convertible to movable brooder house. 8′ x 12′	72711
	Prefabricated grain bins:	
5712	300-bu. movable grain bin convertible to farrowing house	72626
5713	1,000-bu. steel grain bin	73291
5714	2,700-bu. steel grain bin	73292
5715	2,700-bu. grain bin. 14′ x 24′, 10′ stud	73295
5716	1,200-bu. grain bin. 12′ x 16′, 8′ stud	73293
5727	2,000-bu. plywood bin. 16′ x 20′, 8′ stud	73294
5728	1,100-bu. plywood bin. 12′ x 16′, 7′ stud	73296
	Drying-storage units for grain and ear corn:	
5724	Steel bin, 18′ diameter, 9′ to eave. Capacity for drying 1,000 bu. grain or ear corn. Ventilated floor	75503
5725	Movable hog self-feeder, drier, and storage unit. Capacity 1,100 bu. grain	77615
5726	Movable cattle self-feeder, drier, and storage unit. Capacity 1,500 bu. grain	77416

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